Recent trends and outlook of the Spanish energy system[1]

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Abstract

During the last decades the Spanish energy system has become more energy and carbon intensive, and more dependent on external energy resources, although this trend seems to have stopped in the recent years. The regulation of the electricity and gas markets has significantly changed. Two scenarios for the 2030 time horizon are analysed with the POLES-Spain energy model. Under the baseline scenario, the main energy challenges persist even if the energy-GDP intensity reverses its increasing trend. According to a second scenario that assumes significant progress in energy efficiency and higher international energy prices, the energy system undergoes a transformation towards cleaner technologies and renewable energy resources.

1. Introduction

The Spanish economy has enjoyed high economic growth rates during the last decade, following an energy and carbon-intensive development model. Because of its high energy-GDP intensity and an increasing dependency on external energy resources, the oil price outburst that started in 2004 represents a serious macroeconomic risk for Spain. In 2007 energy imports represented 4% of GDP, almost half of the current account deficit.

The purpose of this article is to review the evolution of the energy system and its regulation during the last decade and to explore its possible trends in the 2030 time horizon with the POLES-Spain model. POLES-Spain is a one-country version of the POLES[2] global energy system simulation model. [3, 5, 17] The original POLES model is designed for the development and analysis of long term energy scenarios of energy supply and demand in 47 regions of the world up to 2050. It is a simulation model of the world energy system used regularly to assess climate and energy policies. The main drivers of the POLES model are population, economic growth (GDP), fossil fuel resources and energy technologies of the represented regions.

IPTS has participated in a prospective study of the Spanish energy system for the Ministry of Industry, Trade and Tourism. [12]. This is an (still ongoing) exercise aiming at characterising the potential evolution of the sector in Spain under alternative policy options. Two of the scenarios analysed will be presented in this article: the baseline scenario (BaU) and an energy efficiency scenario (EEF) with high international energy prices. The scenario analysis with the POLES-Spain model, in particular, meets the recently approved 2016 energy planning. [13]

The article is organised in five sections, including this introduction. Section 2 gives an overview of the energy demand drivers of Spain in the last decade. Section 3 reviews the main features of the energy system in the same period, paying special attention to the regulation of energy supply (electricity and gas). Section 4 presents the main results of the two mentioned future scenarios. Finally, section 5 concludes.

[2] POLES-Spain is a variant of POLES (Prospective Outlook for the Long-term Energy System) with a national focus on the Spanish energy system. The POLES model has been jointly developed by the French Centre National de la Recherche Scientifique in Grenoble, with contributions from ECOSIM Ltd., ENERDATA and the Institute for Prospective Technological Studies.

2. Energy demand drivers

Between 1995 and 2006 gross inland energy consumption grew at a 3% cumulative annual rate. Such expansion of energy demand is mainly explained by the following two scale drivers. Firstly, Spain has experienced strong economic growth since 1995 (Table 2.1.), with GDP growing at a 3.7% cumulative annual rate, higher than the EU average. Secondly, during the same period population increased by almost five million reaching 44 million by 2006, which is an unexpected demographic phenomenon (a 10% population increase) at the mid-1990s.

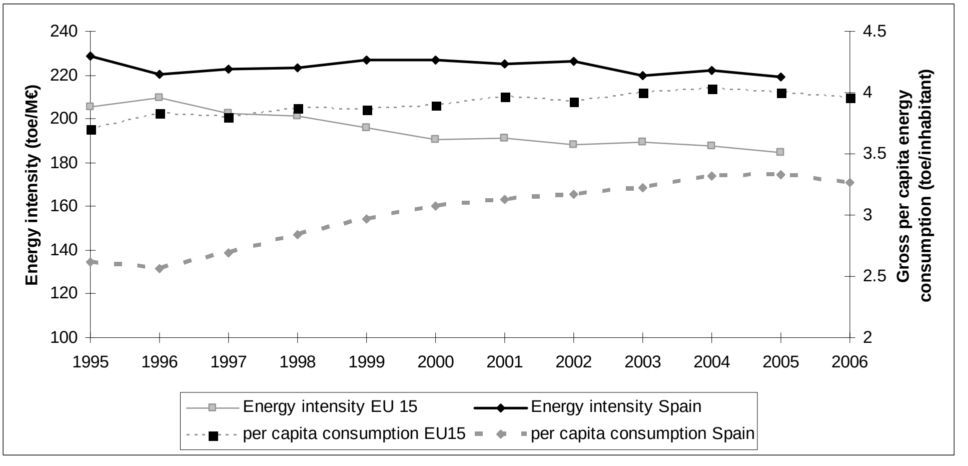
Table 2.1 Key Indicators of the Spanish energy system

	Index 1995=100			*Annual growth rate*		
	1995	*2000*	*2005*	*95/00*	*00/05*	*95/05*
Population	100	102	110	0.4%	1.5%	1.0%
Gross Domestic Product	100	122	144	4.1%	3.3%	3.7%
Gross Inland Energy Consumption	100	120	140	3.7%	3.2%	3.5%
GHG Emissions	100	121	138	3.8%	2.8%	3.3%
Energy-GDP intensity	100	99	96	-0.1%	-0.7%	-0.4%

Source: Eurostat, [4]

Energy-GDP intensity diminished by 4% between 1995 and 2005, whilst the average for EU15 fell by 10% (Graph 2.1.). The consumption of gross energy per inhabitant increased in both the EU15 (7%) and in Spain (25%); however, in Spain it is still around 20% lower than in Europe.

Graph 2.1 Energy intensity and energy consumption per inhabitant in Spain and the EU15



Source: Eurostat, [8]

Greenhouse gas (GHG) emissions grew also substantially. In 2005 Spanish GHG emissions were 52% higher than in 1990, overshooting the 15% Kyoto target for Spain. But even if GHG emissions per capita increased by 25% between 1995 and 2005, they were 7% lower than the EU15 average in 2005.

Another distinctive feature of the Spanish energy system has been the rapidly increasing share of natural gas in gross inland consumption. It rose from 8% to 22% in the 1995-2006 period, associated with a cumulative annual growth rate of 13% in natural gas consumption.

2.1. Primary energy needs and external energy dependency

Spain is one of the European countries endowed with weaker fossil energy resources. Primary energy demand amounted to 145 Mtoe in 2005, of which merely 32 Mtoe were domestically produced (almost half nuclear, a fifth coal, 7% hydraulic, and 14% other renewables).

The combination of growing energy demand with very limited domestic production meant that energy imports increased 53% between 1995 and 2005, amounting to 4% of GDP in 2007. Gas imports experienced the highest growth (284%), followed by coal (60%) and oil (24%). In 2005 the degree of dependency on energy supply was 80%, an increase of 10 percentage points with respect to 1995.

Key oil providers for Spain are Mexico and Russia (around 15% of the supply each of them) and Nigeria, Saudi Arabia, Libya (around 10% each of them). The gas supply structure is less diversified, since Algeria provides around 45% of the imports, followed by Nigeria and Qatar (15% each of them). The gas supply structure relies almost entirely on non-European countries and the role of Russia is marginal. These two characteristics determine the particularities of the gas market in Spain.

2.2. Details of energy demand: electricity, transport sector and natural gas

In 2005 the primary energy mix was dominated by oil (49%), followed by gas (20%), coal (15%), nuclear energy (10%) and renewable energies (6%). This is to be contrasted with the energy mix in 1995, when oil had a much lower share (7%), and oil, coal and nuclear had higher shares (Table 2.2).

<u>Table 2.2</u> Primary Energy demand in Spain

	demand (ktoe)			*Annual growth rate*		
	1995	*2000*	*2005*	*95/00*	*00/05*	*95/05*
Solid fuels	18 518	21 635	21 183	3.2%	-0.4%	1.4%
Liquid fuels	54 610	64 663	71 785	3.4%	2.1%	2.8%
Natural gas	7 504	15 223	29 120	15.2%	13.9%	14.5%
Renewables	5 490	6 776	8 545	4.3%	4.7%	4.5%
Nuclear	14 449	16 211	14 995	2.3%	-1.5%	0.4%
Total	100 572	124 507	145 628	4.4%	3.2%	3.8%

Source: IDAE

Net electricity generation has grown even at a higher rate than final energy demand, at a cumulative annual rate of 5.6%. In addition to a strong income effect, electricity demand was boosted in the 1995-2005 period by the evolution of electricity prices, which fell in nominal terms by 17% and 12% for industrial and domestic uses, respectively.

In 2005 final energy demand of the transport sector represented 41% of the total (whilst in the EU15 it was 31%), followed by the demand in industry (30%), the domestic sector (15%) and the service sector (12%).

3. Energy supply and regulation

Each energy subsector (power generation, gas, refining & oil, etc.) has experienced important regulatory changes during the last 10-15 years, most of them aiming at introducing a higher level of transparency in the price formation mechanisms and liberalising the supply. The role of the public sector in energy supply is now negligible. A centralised regulatory body of the energy systems was established in 1998, the Comisión Nacional de la Energía.

3.1. The oil and gas subsector

The oil monopoly, Campsa, was dismantled by law in 1998. This regulatory change facilitated the creation of the company responsible for the operation of the transportation network (CLH SA), liberalised consumer prices and enabled new entrants into the sector. The oil sector is now articulated as an oligopoly with three major players, Repsol, Cepsa and BP. They have been sometimes suspect of collusive practices, preventing newcomers from entering the market and interfering in the prices [1,14]. Since its privatisation, Repsol has grown internationally via takeovers and mergers. Even if it has now become one of the 10 largest world oil companies, it still misses critical mass to compete in a global market where marginal resources are becoming more and more expensive to discover and exploit and where the competition for them crucially depends on extra-economic aspects.

Natural gas has experienced a significant penetration in the Spanish energy mix in the past years, not only due to the emergence of combined cycles in the power sector, but also because it has displaced a significant share of liquid fossil oils and coal in the industrial, residential and tertiary sectors. The 1998 Hydrocarbon Bill introduced a new liberalisation scenario in the sector, with "qualified consumers" label, i.e. those able to participate in the market, progressively extended to all consumers by 2003. Consumers were able to choose between the regulated market (with prescribed prices depending on the delivery conditions) or to negotiate a bilateral contract with any gas commercial distributor. The former approach represents now around 90% of the total sales. However, in terms of transactions, the free market represents a fraction below 40%, since individual domestic consumers and SMEs represent a low fraction of the total consumption. The market has a dominant agent, Gas Natural SA, which was obliged by the above-mentioned law to segregate the activities related to the operation of the system and some of the regasification plants (now Enagas). However, the degree of monopoly in the Spanish gas sector is still lower than the average in other EU member states.

The gas network has expanded rapidly since the first north-south gas duct was connected through the Pyrenees to the French network in 1993. Since then, and for geographical reasons, the peninsular network (including Portugal) has evolved towards a system primarily based on regasification plants (seven including the Portuguese in Sines) and three main connections with international gas ducts (with Morocco through the Strait) and two more with France. Regasification terminals represent now almost 80% of the supply capacity to the gas networks. As a consequence, one of the distinctive features of the Spanish gas market is the important role played by LNG, which has facilitated a significant diversification of the supply, and higher flexibility to accommodate demand fluctuations. The need for storage hubs was not highly pressing during the deployment phase of the gas network, but this deficiency of the system is now becoming the more and more critical. There are plans to increase the gas duct connections by constructing a line to Algeria.

It is generally admitted that the future of the gas sector will be highly linked to the power generation sector, as it has been in the past decade. Therefore, the evolution of the gas market structure will determine also the one in electricity generation, especially for what concerns prices, since the combined cycle technology operates at the margin and sets the price in the power market.

3.2. The electricity subsector

The power sector was reorganised in Spain by an electricity bill issued in 1997, transposing the corresponding 1996 EU Directive. This bill introduced substantial reforms in the sector, allowing new entrants and facilitating the supplier choice from "qualified consumers". This category has been broadening and now includes a very large share of the total consumption. A wholesale spot market was organised through a pool, where generators bid and distributors and qualified consumers demand on an hourly auctioning basis. The participation in the pool is not obligatory: market agents can contract bilaterally also. In addition, the bill stipulates a "special regime" for the generation of electricity with particular technologies and/or special fuels. For the renewables, traditional hydropower stays in the pool, whereas the rest of them (wind, biogas, biomass, photovoltaics and high temperature solar thermal) benefit from a "feed-in" system with subsidized tariffs, periodically reviewed. The "special regime" was extended to co-generation in different modalities and some forms of domestic coal, but these are shrinking and the non-competitive market fringe is evolving towards a technology-differentiated (and quite successful) "feed-in" tariff system, giving though the opportunity to these producers to apply to the competitive pool. [10]

The Spanish power system is an imperfect duopoly (ENDESA and Iberdrola SA are the leading actors), with companies having quite differentiated technological profiles. The reduced number of suppliers fosters strategic, predatory practices that depend on the prevailing technology for each individual producer and erode the market efficiency.

The spot market was organised until 2006 on a pure marginalist basis, i.e. all offers were remunerated at the pool price, theoretically determined by the marginal power plant – a natural gas in combined cycle.

The experience of the operation of the electricity pool in Spain (as in many other countries) tends to indicate that it provides with a system of incentives too focused on the short term, disconnects the long-term planning investments from revenues and, because of the price volatility, makes it difficult the price-driven demand response [7]

A legislative modification took place in 2006, basically tending to bilateralize the market. For instance, all transactions made between generators and distributors belonging to the same corporation have to be considered as bilateral contracts [16] As a consequence, in addition to the spot price, several prices appear, remunerating each bilateral bid according to the contracted price. The regulatory framework is, therefore, in process of change and probably will evolve towards a system in which bilateral contracts with discriminatory prices will prevail [18]

The market of spinning reserve has been also organised aiming at providing incentives for capacity availability and, ultimately to foster investments in power generation, and since 2005, bilateral contracts are also subject also to the spinning reserve payments.

The co-existence of a wholesale competitive market with free prices and a retail market on which distributors dispatch power to ("non-qualified") consumers at a tariff prescribed by the Administration represents a challenge for the stability of the system (as in many other countries, most painfully in California). The process of electricity liberalisation took place during the late 80's and the 90's under the generalised expectations of long-term price decline. The development of natural gas turbines in combined cycle (GTCC) as a cheap, affordable and competitive technology with low capital costs, high energy conversion efficiency and prospects of abundant and safe fuel provision put the technological basis for the industry to change towards the competitive market. In Spain, GTCCs (and wind turbines) have represented the bulk of the additional capacity installed during the last 10 years. GTCCs have passed from virtually zero in 2000 to more than 16 GW by 2007. However, natural gas prices have followed a rising path and the prospects of contained prices for natural gas have been reverted in the last years, especially in European markets. The mismatch between wholesale free prices determined by increasing generation costs and retail prices directly prescribed by the Administration has created a growing volume of financial loss to distributors, the so-called "tariff deficit": from around 1000 M€/year in 2000 to 3800 M€/year in 2005. These losses are financed by the banking system by means of a credit instrument issued with the guarantee of future cash-flow to utilities. In spite of the attempts of the Administration to mitigate this via regulatory mechanisms, the definitive solution of this will is likely to come only via translation of the rising power generation costs to the final consumers. Therefore, the prospective of rapidly growing electricity final prices for the forthcoming decade seems very likely.

Spain's power sector is also characterised by a firm, sustained support to renewable power systems. The most successful schemes corresponds to wind energy, because of the good potential of the Spanish geography, the relatively affordable structural costs of this technology and the "feed-in" system implemented, periodically reviewed and updated. The installed capacity has evolved very rapidly: from 2.2 GW in 2000 to 15 GW by the end of 2007. In terms of production, wind energy represents a substantial share of the Spanish electricity mix. According to the preliminary estimates of Red Eléctrica de España, wind turbines produced 10% of the 276 TWh consumed in 2007. The "Plan de Energías Renovables" of the Ministry of Industry establishes an objective of reaching the 20 GW installed by 2010, an objective that seems reachable with the policies in place. Long-term (2030) targets may be as ambitious as 40 GW, although the corresponding production levels are likely to pose managing problems that necessitate to be overcome. The role of hydropower as load-tracking technology is expected to be more and more limited by the shrinking resource availability. On the other hand, the peninsular electric system lacks appropriate interconnection with the rest of Europe that would facilitate the evacuation of production peaks and the supply of backup if domestic backup fails. The emergence of more manageable renewable technologies (like high temperature solar thermal) will not alleviate this problem, and therefore a careful design of the spot dispatch will be necessary in the future to accommodate all non-manageable power sources, including the 7 GW of nuclear power delivering almost 20% of the total consumption (2008). The role of GTCC groups and pumping storage for backup and load-tracking will be therefore fundamental.

4. Energy outlook to 2030

The Spanish government has recently concluded a prospective analysis of the energy system in the 2030 time horizon, using several methodologies and sectoral studies. The POLES-Spain model is one of the models run to assess the effects of a set of scenarios. The main advantage of using a multi-country quantitative model such as POLES-Spain for the analysis of a country's energy system is that it permits a harmonised and systematic treatment of global policies, capturing at the same time the functioning of the key global energy markets. They act as boundary conditions for the dynamic evolution of a domestic energy market.

The main results of two scenarios from the above-mentioned study are presented in this section. The first scenario follows the historical trends of the energy system without any additional policy influence. It is called baseline scenario (BaU). The results of an energy efficiency scenario with high international energy prices are also presented (EFF). This second scenario is at the other end of the range of the scenarios considered in the prospective exercise. It leads to a very different energy system by 2030, characterised by lower energy intensity, increasing role of renewable energies and less dependency on external energy resources. The main drivers for such transformation are major energy efficiency improvements and much higher international oil and natural gas prices.

The main socio-economic assumptions common to both scenarios are described in the upper part of Table 4.1. GDP is assumed to growth at high rates, gradually converging to the long-term growth rate of the EU, 2%. Population grows at much lower rate than in the 1995-2005 decade, and stabilises at 46 million by 2010-2020. As a result, GDP per capita grows at 2% per year at the end of the 2005-2030 period. Concerning the number of dwellings, they increase at a lower rate than GDP, reaching around 20 million by 2030.

The assumptions on energy efficiency and the international energy prices appear in the lower part of table 4.1. In the baseline scenario, it is assumed that the targets of the current energy efficiency policies are achieved and, in particular, the Energy Saving and Efficiency Strategy 2004-2012. Energy efficiency[3] [6, 9] can be modelled with POLES-Spain through two channels. On the one hand, the autonomous energy efficiency improvement parameter (AEEI) captures the efficiency gains of the specific energy technologies. The second mechanism of energy efficiency gains is induced by the endogenous changes in the prices of resources, investments and income in the model. In the baseline scenario sector-specific values for the AEEI parameter are applied in the -0.5% to +0.5% range. These are gradually increased to the range of -0.5% to -1.5% in the EEF scenario in the period of 2008-2020. These AEEI values reflect continuing harmonisation with the EU trends in the long term and the commitment of the country of saving 20% of primary energy with respect to the BaU scenario by 2020. The underlying assumption for the energy efficiency scenario is that market agents become less and less myopic to identify and apply low or even zero cost efficiency gains in the sector and the application of these energy-saving technologies triggers a virtuous feedback loop inducing further AEEI improvements.

[3] The average yearly energy intensity improvement values for the different sectors in the EU (Spain in brackets): industry -2% (-1%), household -2.3% (0,7%), services -1,3% (1,7%), transport -0,1% (0,6 %), agriculture -0,4% (0,2%) for the 1980-2004 period. [7]

Concerning international energy prices, there is a big difference between the BaU and the efficiency scenario. While under the BaU oil prices are 51 €/bbl in 2020 and 74 €/bbl in 2030, they reach in the efficiency scenario 61 €/bbl and 94 €/bbl in 2020 and 2030, respectively. The natural gas prices follow a similar evolution.

<u>Table 4.1</u> Basic assumptions in the BaU and EEF scenarios

1) Socio-economic assumptions							
Terms / years	**Absolute terms**				**Annual growth rate**		
	2005	2010	2020	2030	2005/ 2010	2010/ 2020	2020/ 2030
GDP (MEUR in PPP)	863	1019	1302	1587	3.3%	2.4%	2.0%
Population (Mcap)	43	45	46	46	0.8%	0.3%	0.0%
GDP per capita (EUR/cap)	20107	22787	28275	34452	2.5%	2.1%	2.0%
Number of Dwellings (1000)	15247	17083	19388	20247	2.2%	1.3%	0.4%

2) Binding legislative and policy representation	
BaU	**EEF**
2.BaU.A Energy efficiency targets set down[a]	**2.EEF.A.** Increased AEEIs to 1,5% + primary energy saving of 20% by 2020 with respect to BaU
	2.EEF.B Additional increase in world oil (94 €/bbl) and natural gas (75 €/bbl) prices by 2030 (more constrained supply).

Notes:
a) The energy efficiency targets are set down in the Energy Efficiency in multisectorial policies, concretely in Strategy for Energy Saving and Efficiency for Spain, Action Plan 2005-2007 and 2008-2012. AEEI = Autonomous Energy Efficiency Indicator.

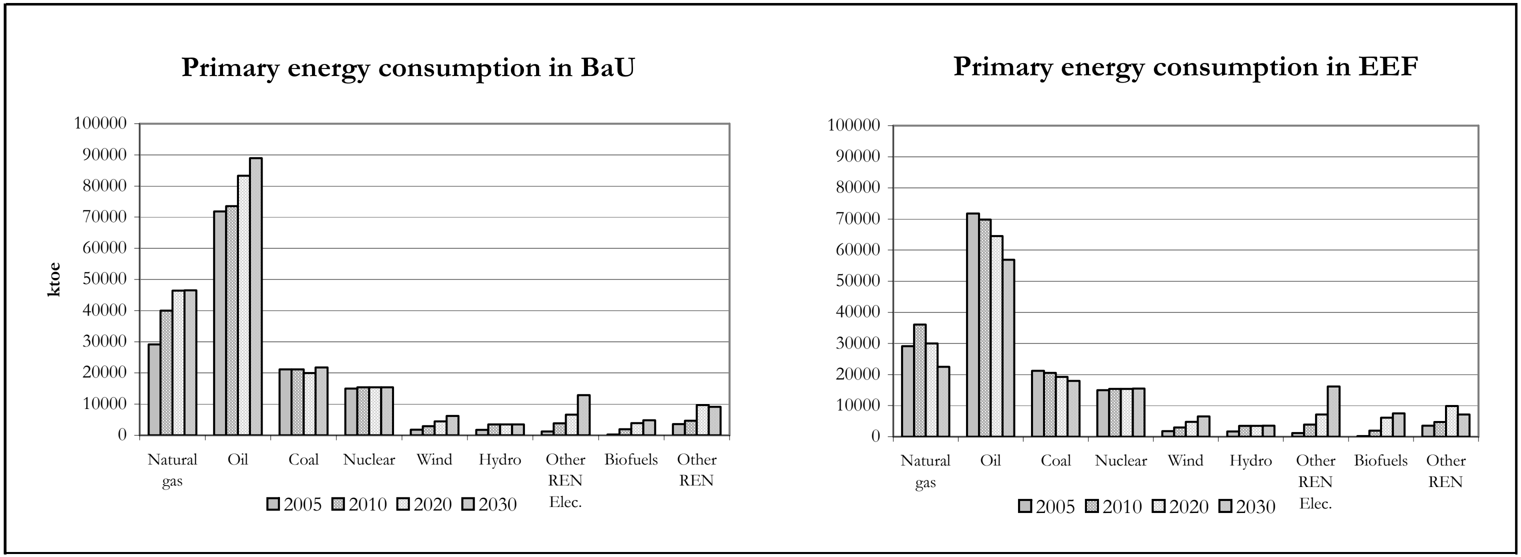
Moreover, there is a set of assumptions common in both scenarios. Firstly, it is assumed that the economic lifetime of the current nuclear power plants is extended to 2030. Secondly, the production of the renewable sector and its dynamic evolution follow the requirements established by the EU and the commitments of the Spanish legislation as of the fuel-mix (20% of all primary resources should come from renewable by 2020), the low temperature solar panels in buildings and the biofuel target (10% of total fuel consumption should be covered by bio-combustion fuel and 5.75% of all road transport should come from biofuel as well). Thirdly, carbon-abatement commitments are modelled through an application of 18€/tC carbon value for all the European countries on those sectors that participate in the ETS. Finally, the existing structure of subsidies to electricity generation with renewable energies in place in Spain is assumed (the "feed-in" tariffs).

4.1. The evolution of energy demand and security of supply of the future Spanish energy system

In both scenarios the energy-GDP intensity reverses its (stable) evolution during the last decade and starts to fall as primary energy consumption grows less than the economy. The efficiency improvement in the case of the EEF scenario is more pronounced. In this case, the gross inland consumption to GDP ratio would fall by 40% between 2005 and 2030, while it would fall by 27% under the BaU scenario.

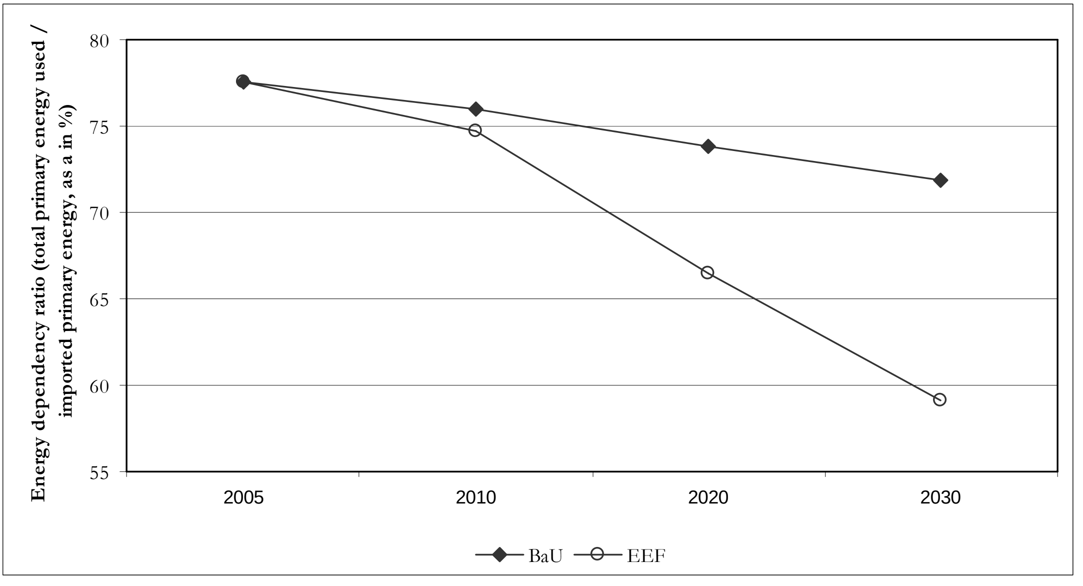
Graph 4.1. represents the evolution of primary energy consumption by fuels in the 2005-2030 period. It is interesting to note that under the BaU the penetration of natural gas in the energy system is practically completed by 2020, while coal and nuclear consumption remain approximately constant over the whole period. The results of the BaU scenario are consistent with the trends of recent years with both renewable energy resources and natural gas increasing their weight in the energy mix of the country in detriment of oil and coal. Indeed, in both scenarios the presence of renewable resources increases considerably, more than tripling over the 25 years period. Under the EEF scenario, consumption of all fossil fuels decreases in the 2010-2030 period.

Graph 4.1 Gross inland primary energy consumption



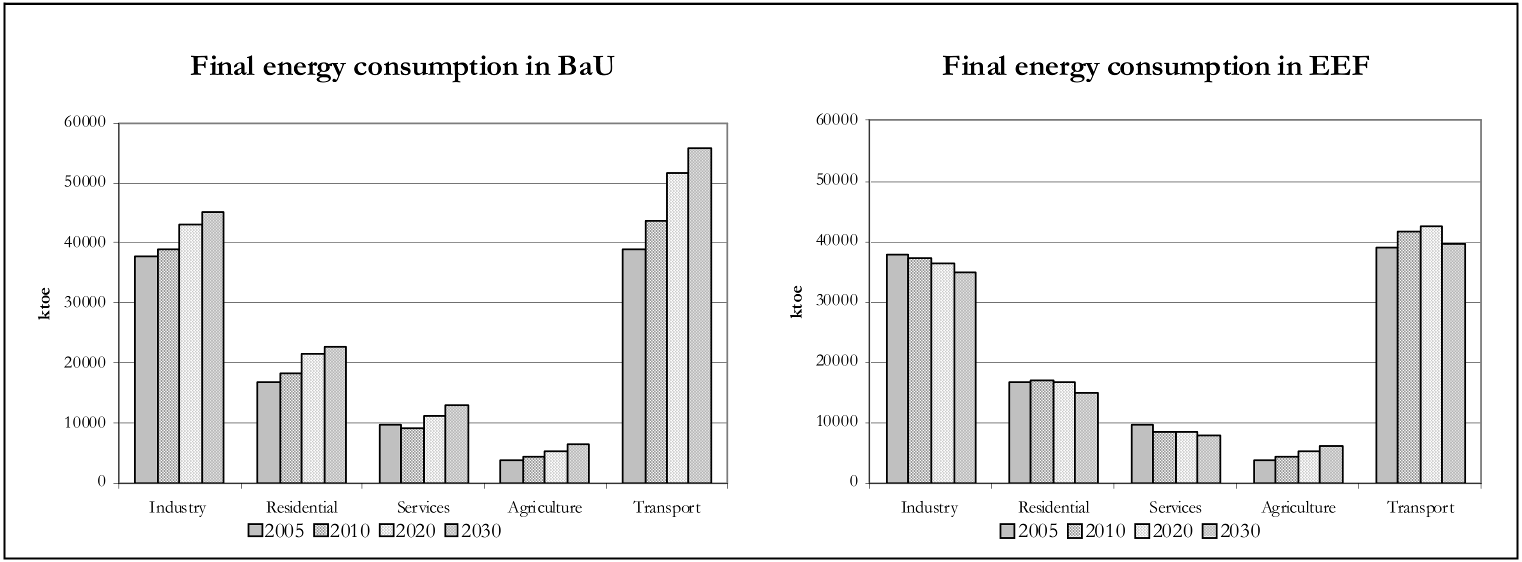
The significant expansion of renewable sources explains the drop in the energy dependency ratio, even if the overall energy demand enlarges. In particular, the dependency ratio (Graph 4.2.) improves with respect to the present value (78%) not only in the EEF scenario (59% by 2030) but also in the BaU (72% by 2030).

Graph 4.2 Evolution of the energy dependency ratio



Concerning the final consumption by sector (Graph 4.3.) , under the BaU scenario the current trends continue: energy demand of transport, residential and service sectors show an annual increase of above 1% from 2005 throughout 2030, while agriculture's demand increases above 2% due to intensive cultivation. On the contrary, in the EEF scenario the energy consumption of industry, residential sector and services decrease for the whole period (at annual rates of 0.3%, 0.5% and 0.8%, respectively). It is remarkable that the transport sector would decrease its total energy consumption: the general driver of more expensive international energy prices is accompanied by large technological improvements in the car fleet, as discussed later.

Graph 4.3 Final energy consumption by sector



4.2. The electricity sector in the BaU and EEF scenarios

Under the BaU scenario the POLES-Spain model projects electricity consumption to grow higher than 4% annually for the 2005-2010 period. This growth smoothly decreases to 1.6 % in the 2020-2030 period in the BaU scenario and to 0.7 % in EEF scenario. By 2030 electricity demand is almost 25% lower in the EFF scenario than in the BaU scenario.

The new demand will be mainly satisfied with increasing natural gas capacities in the electricity portfolio, as happened in the last few years. Such 'dash for gas' process is expected to peak around 2020, showing an early saturation level, mainly due to the high natural gas prices. In 2030 gas-fired capacity reaches 23 GW under the EFF scenario and 30 GW under the BaU. The relatively larger expansion in the BaU is explained by the different behaviour of natural gas price assumed in the scenarios (it more than doubles in the BaU, and triples in the EEF scenario). Power generation is expected to account for more than two thirds of natural gas consumption by 2030 in both scenarios. More than a third of electricity could be generated from gas by 2030 (GTCC).

Such development entails the risk that the gas-fired capacity accumulation is very concentrated in time, which can disturb later investment (replacement) cycles. As these capacities arrive to the end of their lifetime in a short period (after around 20-25 years from now), it would also require substantial investments. This would leave the investments cyclical for the sector and would also result in a distorted age structure of the capacities.

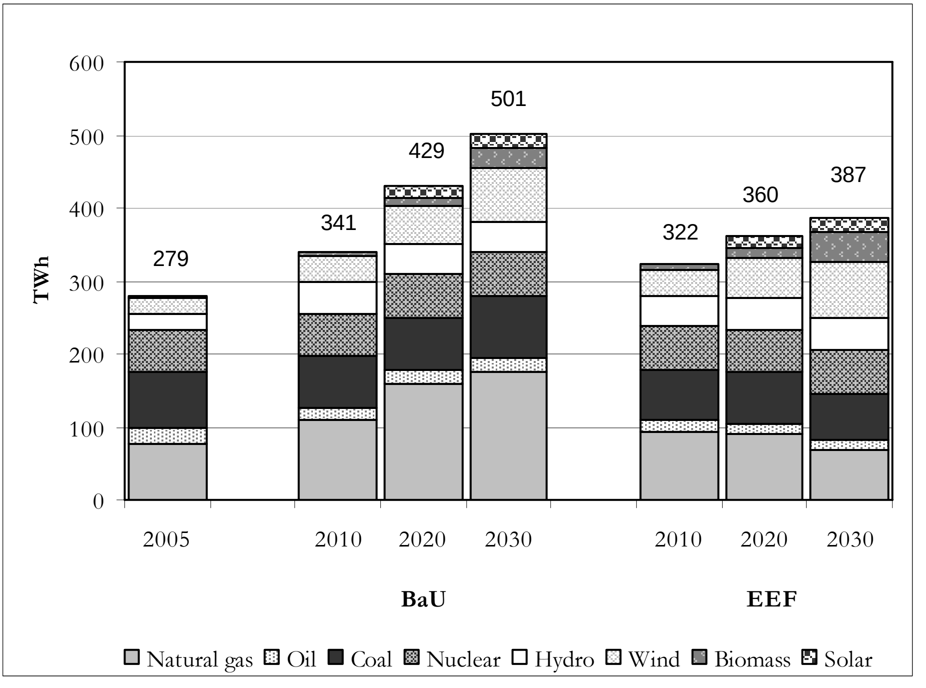
Furthermore, GTCC will serve as back-up in a future system characterised by a high ratio of intermittent renewable capacities.

Coal plays a significant role in the present electricity system, accounting for 25% share in 2005 with a strong resource base in the country. Ministerial orders and the ETS already limit the role of the coal-based technologies, which is reflected in the changing age structure of coal capacities and the lack of investments in this segment. In spite of these limitations, the model foresees increases in emerging coal technologies from 2015, namely in the pressurised fluidised-bed reactors and coal gasification technologies. With increased efficiency and more effective filtering of the effluent gases, the new coal technologies show potentials to occupy the place of the out-going obsolete capacities. Given the relatively low carbon value assumed in the scenarios no significant carbon capture and sequestration capacities (CCS) are expected to appear yet in the future generation portfolio.

Hydro and wind represent more than 40% of the existing overall electricity capacity, while their contribution to generation is between 15% and 20%. The present high share of hydro brings uncertainty into the electricity system because water collected in the catchments competes for three different uses: drinking water (especially important in dry, tourist areas), irrigation for agriculture and electricity generation. This latter use has less priority compared to drinking water and agricultural uses. In 2005, a dry year, hydro electricity generation fall significantly, highlighting the volatility of this resource. Additionally, as most of the potential sites are already in use, no increase in capacities is foreseen in the future for this technology. The long-term climate forecasts for Spain are even more pessimistic about water availability, the projections show high probabilities of reducing levels of precipitations in the Peninsula on the long term. [11, 15]

In the mid and long term wind technology is expected to maintain strong growth rates, while solar is expected to soar from 2010 on, with the solar thermal power plants being the driver of this development. The assumption of maintaining the present subsidy system is a pre-requisite of this strong development. In wind technologies the development is two-staged: till 2020 mainly on-shore plants are built, while in the second interval off-shore construction takes off. A third important element is biomass in the renewable electricity portfolio, which also shows relatively strong growth through the whole period (close to 50% increase by 2030). All these developments achieve a strong impact on the future electricity generation system. High share of electricity is projected to be generated in the future energy system from renewable sources (33% to 46%, respectively for the BaU and EEF), of which more than half is intermittent solar and wind), which also pose challenges to the manageability of the system. Constructing new inter-connection lines for buffering with the neighbouring countries would also help in this respect.

<u>Graph 4.4</u> Net electricity generation in the different scenarios



In summary, the assumed efficiency improvements and the high fossil fuel prices, mainly through the natural gas price, have significant impact on the whole electricity system by reducing the total demand for electricity (around 20% by 2030). This also helps in transforming the generation portfolio to a more secure (means less dependent on foreign resources) and less natural gas-intensive one, which in a long term helps to develop a more sustainable electricity system. As strict assumptions are employed in the modelling (*e.g.* keeping nuclear capacities and inter-connection lines constant) the usual caveats apply meaning that the results should be treated as comparative scenarios, rather than forecasts.

4.3. Future trends in the transport sector

Final energy consumption in the transport sectors, particularly road transport, shows high growth rates in the period. Road transport accounts for 80% of fuel consumption in the sector, and it keeps this share up to

2030 under the BaU scenario. In the EEF scenario the assumed further increase in oil prices has significant effects, and the final energy consumption reduces by 20% by 2030 under the EFF scenario compared to the BaU scenario.

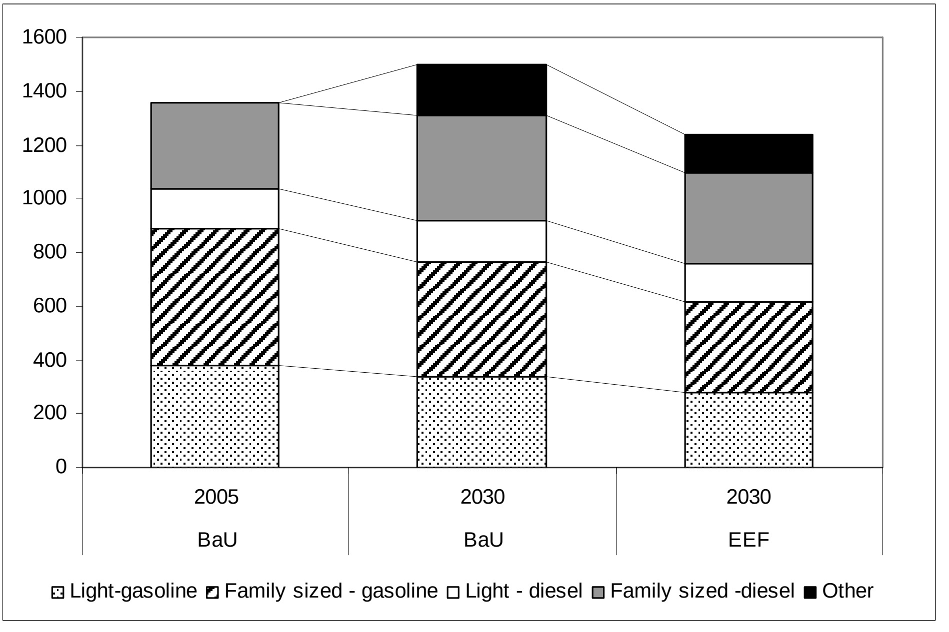
The car fleet and the total vehicle-km driven also follow a dynamic path, where the main drivers are the population dynamics and the income growth assumed in the model. Again, the BaU and EEF scenarios show clear differences to this respect: moderate growth at the end of the period in the BaU scenario, while reduction in absolute numbers for the car fleet and for the total km driven in the EEF scenario.

All these changes are accompanied by significant efficiency improvements in the vehicle propulsion systems. On average, car efficiency improves by 24% in the baseline and by 30% in EEF in the period of 2005-2030[7]. There are many different adjustments taking place in the car fleet. First, the trend of 'dieselisation' would be maintained from the beginning of the period together with the car size changes, mainly through increasing the shares of the light diesel vehicles. Even if diesel prices tend to rise more rapidly, the better efficiency of the diesel engine would compensate for the cost increases. The conventional engines also undergo significant efficiency improvements, while the appearance of new propulsion system cars (mainly hybrid and electric cars) is another element amongst the adjustments the sector undergoes, as Graph 4.5. illustrates.

Concerning biofuels in the transport sector, in order to reach the 5.75 % target share[8] for 2010 biofuel use has to almost double in the first five years of the period. This is a target which could only be achieved by large imports in Spain. The EEF scenario shows that even with high oil prices the biofuel share does not reach 20% by 2020.

[7] 0.154 Ktoe/mKm in 2005, 0.118 Ktoe/ mKm in BaU and 0.107 Ktoe/ mKm in EEF in 2030.
[8] In the scenario it is assumed that that target is reached by 2010.

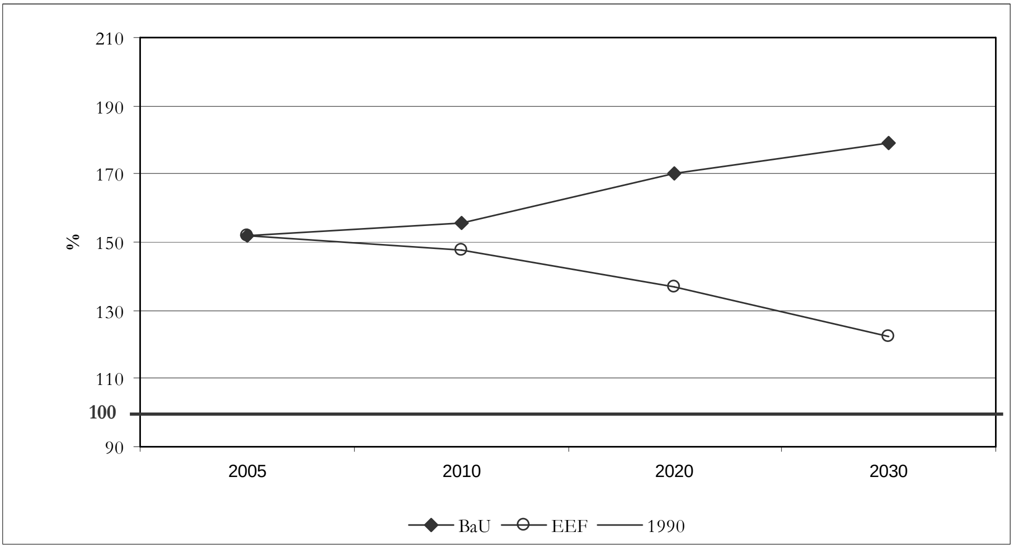
<u>Graph 4.5</u> New car registration (thousand cars)



4.4. GHG Emissions

GHG emissions in the BaU scenario continue growing significantly (being by 2030 80% higher than in 1990), while they fall under the EEF scenario (Graph 4.6.), reaching 123 % of the 1990 level by 2030. Energy efficiency improvements bring results in the long term, as they are usually connected to longer term investment cycles. [2, 6] The improvements achieved in the EEF scenario are the results not only of the assumed efficiency gains but also of the higher fossil fuel prices. This shows that the Spanish economy has potential of reducing GHG emission in the long term, especially taking into account the relatively low carbon value applied in the scenario.

Graph 4.6 Evolution of GHG emissions in BaU and EEF



5. Concluding remarks

The recent evolution of the Spanish energy system has three distinctive features compared to its European competitors. Firstly, the energy-GDP intensity remains high. Secondly, GHG emissions are largely exceeding the target for the 2008-2012 period. Thirdly, the Spanish economy is much more vulnerable to high international energy prices as Spain imports most of its fossil fuel consumption.

The POLES-Spain model, a simulation energy model, has been run to assess two possible future scenarios of the Spanish energy system in the 2030 horizon. According to the baseline scenario, some positive progress is made in the three noted aspects. Thus, the external energy dependency rate falls from 78% in 2005 to 72% in 2030. Energy-GDP intensity also falls because of the decrease in the rate of growth of both electricity and transport demand. Yet GHG emissions stay 55% and 79% above 1990 levels in 2010 in 2030, respectively.

Under the energy efficiency scenario, which also assumes much higher oil and natural gas prices than the baseline, a general improvement in all the indicators occur. In particular, the higher international energy prices induce a much higher drop in energy-GDP intensity. The dependency rate is projected to be 59% in 2030, more than 20 percentage points lower than today's. GHG emissions, while still above the Kyoto target in 2010, could be 23% higher than the 1990 level in 2030.

The sectoral analysis of the scenarios results shows a series of concerns in the Spanish energy system. First of all, both the EEF and the BaU scenarios highlight the risks of the rapid development of GTCC capacities. This technology accounts currently for two thirds of the new investments in the power sector. Volatility of natural gas prices could result in significant high sunk costs, questioning the strong investments undertaken in this technology. Additionally, the higher penetration of natural gas, entirely imported, raises the energy supply dependency of the country.

The exposure to both risks (financial and security of supply) could be managed by diversifying the supplier side, and also by improving the gas interconnection lines with the neighbours. A positive element is that the diversification of the LNG supply is an on-going process, so Spain does not share the problem of many gas-importing European countries *i.e.* to be too dependent on imports from Russia.

A second concern relates to the fact that higher share of renewables in the energy mix (achieving 46% in 2030) makes indispensable enlarging the capacity of inter-connection lines of the Spanish electricity system as well, currently rather isolated.

The power generation system faces additional challenges on the financial side as well. The public authorities need to address the problem of tariff deficit, accumulated during the past years by maintaining consumer prices below electricity costs. A further pressure on the electricity price will come from the feed-in tariff system of renewables. The challenge here is to maintain the tariff levels attractive enough to preserve the high level of investments in renewables, without putting unsustainable pressure on the cost side.

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